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2.	Patent application number *(The Patent Office will fill in this part)*	0308951.3
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Azea Networks Ltd. Bates House Church Road Harold Wood, Romford Essex, RM3 0SD
	Patents ADP number *(if you know it)*	8529455001
	If the applicant is a corporate body, give the country/state of its incorporation	UK
4.	Title of the invention	TOP-FLAT SPECTRUM DATA FORMAT FOR Nx40 Gbit/s WDM TRANSMISSION WITH 0.8 Bit/s/Hz SPECTRAL EFFICIENCY
5.	Name of your agent *(if you have one)*	Gill Jennings & Every
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Broadgate House 7 Eldon Street London EC2M 7LH
	Patents ADP number *(if you know it)*	745002

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day / month / year)*
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8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES

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Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	0
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	NO

11. For the applicant
Gill Jennings & Every

I/We request the grant of a patent on the basis of this application.

Signature: Gill Jennings & Every

Date: 17 April 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

FINNIE, Peter John
020 7377 1377

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TOP-FLAT SPECTRUM DATA FORMAT FOR Nx40 Gbit/s WDM TRANSMISSION WITH 0.8 Bit/s/Hz SPECTRAL EFFICIENCY

We examine a signal format with top-flat spectrum and corresponding sinc temporal profile resonancely placed over few time slots. Due to sharp decay of the spectrum such a format has low cross talks in dense WDM transmission. A feasibility of WDM transmission at 40 Gb/s channel rate over 1200 km without FEC with spectral efficiency of 0.8 bit/s/Hz (without polarization division multiplexing) is confirmed by numerical modelling.

Introduction. Rapidly growing aggregate capacity of optical communication systems places special emphasis on the spectral efficiency of data transmission. Transmission with densely spaced channels at high bit rates (40 Gb/s and more) is an attractive technology that has progressed rapidly during last few years [1-4]. New data formats have been suggested recently aiming to find an optimal balance between cross-talks, resistance to noise and nonlinear impaiments. Dense channel spacing predominantly assumes narrow filtering of signal to suppress cross-talks. This, however, produces a corresponding corruption of signal in time domain. Transmission of band-limited signal has already been studied for return-to-zero (RZ) signal at 40 Gb/s channel rate [5]. However, a temporal shape of the carrier pulse was not specifically controlled in [5]. In this Letter we examine Nx40 Gb/s WDM transmission using data format with top-flat spectrum over bandwidth B and temporal profile sinc(πBt). To produce a carrier with such a temporal form, it is proposed to send very short (1.7 ps in this particular case) pulses through band-limiting optical filter. Due to sharp decay of the spectrum outside the signal band, transmission channel with such a carrier has high tolerance against narrow filtering. On the other hand, an overlap between neighbouring bits in the time domain leads to strong patterning effects. Using sinc-shaped pulses it is possible to suppress impact of neighbouring bits by positioning periodic zeroes of sinc(πBt) in the center of time slots.

op-flat spectrum data format. To produce sinc-shaped carrier with top flat spectrum, short (1.7 ps) Gaussian pulses has been sent through the super-Gaussian optical filter. Figure 1 shows temporal profile of the pulse before (top) and after the optical filter. Note that the zeroes of sinc(πBt) are adjusted to the middle of time slots reducing corruption of eye for the neighbouring bits.

Figure 2 illustrates how WDM signal is formed using top-flat spectrum carrier signal. Top picture shows pulse spectrum before applying optical filter (shown for selected channel below the top). Next two figures depict signal spectrum after band-limited filtering at the transmitter and mixed WDM channels after propagation over 980 km (bottom).

Important features of band-limited sinc-shaped pulses are illustrated by Fig. 3 where eye-diagram of the signal at the transmitter is plotted. Here optical filter is shifted by – 4 GHz against the center of the signal spectrum (as shown in Fig. 2). It is seen that due to resonance locations of sinc(πBt) zeroes the eye can be kept relatively open even in the presence of strong patterning effects caused by slow decay of sinc-shaped pulses. Note that the waveform of top-flat spectrum sinc-shaped data format shown in Fig. 3 is very different from both the band-limited RZ signal considered in [5] and from NRZ waveform.

Transmission simulations. As a particular example, without loss of generality we examine performance of the band-limited sinc-shaped pulses in Nx40 Gb/s WDM transmission with 50 GHz channel spacing. As an illustrative example we consider a periodic symmetric dispersion map SMF (20 km) + DCF (6.8 km) + SMF (20 km) + EDFA with the total length of 46.8 km. Parameters of the fibers are as follows (a) SMF: dispersion at 1550 nm D = 17 ps/nm/km, slope S = 0.07 ps/nm/nm/km, $A_{eff} = 80\,\mu m^2$, loss 0.2 dB/km; and (b) DCF: D= -100 ps/nm/km at 1550 nm, slope S = -0.41ps/nm/nm/km, $A_{eff} = 19\,\mu m^2$, loss 0.65 dB/km; EDFA has a noise figure of 4.5 dB. Span average dispersion has been optimized with the

...st performance observed at <D> = - 0.03 ps/nm/km. Transmission of 8 WDM channels located from1548.78 nm with 50 GHz separation has been modelled. MUX and DEMUX are made of optical super-Gaussian filters (6 order) with the bandwidth 40 GHz and possible detuning (optimized at the transmitter and the receiver) across the channel. Very short 1.7 ps pulses with 57 mW peak power have been filtered by optical filter of 40 GHz bandwidth producing band-limited sinc-shaped pulses (as shown in Fig. 1) with the averaged power of -5dBm. Received signals are directly detected with conventional 40 Gb/s receiver with Butterworth electrical filter having bandwidth of 50 GHz. A system performance has been analysed in terms of maximum propagation distance corresponding to a linear Q > 6.

Figure 4 shows the error-free transmission distance as a function of the filter detuning. Note that the optimal detuning is sensitive to the optical filter shape. For instance, using super-Gaussian filter of the sixth order it can be found that the optimal detuning is shifted to – 6 GHz. We would like to emphasis that the technique of narrow-bandwidth filtering and exploitation of band-limited modulation format requires optimal combination of optical filter detuning and electrical filtering.

Figures 5,6 show optical signal after transmission over 1200 km (the best regime in Fig. 4). Figure 5 depicts an optical eye diagram for the worst channel and Fig. 6 shows WDM spectra after 1200 km.

Conclusions. We have examined band-limited signal format with sinc-shaped temporal profile resonancely placed over few time slots. Sharp decay of the spectrum and corresponding suppression of WDM cross-talks has allowed to achieve spectral efficiency of 0.8 bit/s/Hz with equally polarized channels. A feasibility of WDM transmission at 40 Gb/s channel rate over 1200 km without FEC with spectral efficiency of 0.8 bit/s/Hz is confirmed by numerical modelling.

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2. C. Rasmussen et al: 'DWDM 40 G transmission over trans-Pacific distance (10,000 km) using CSRZ-DPSK, enhanced FEC and all-Raman amplified 100 km UltraWave fiber spans', Proc. OFC'2003, 2003, PD18-1.
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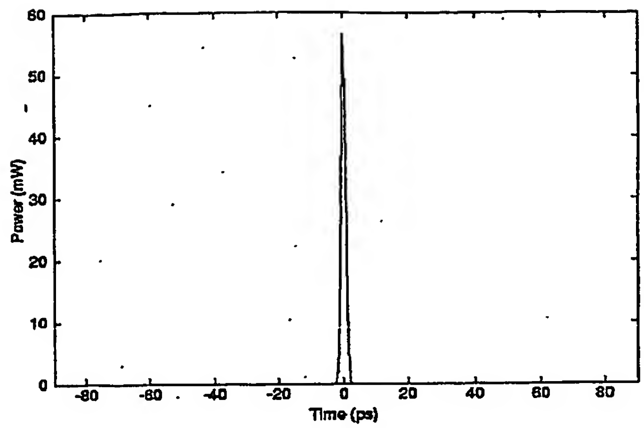

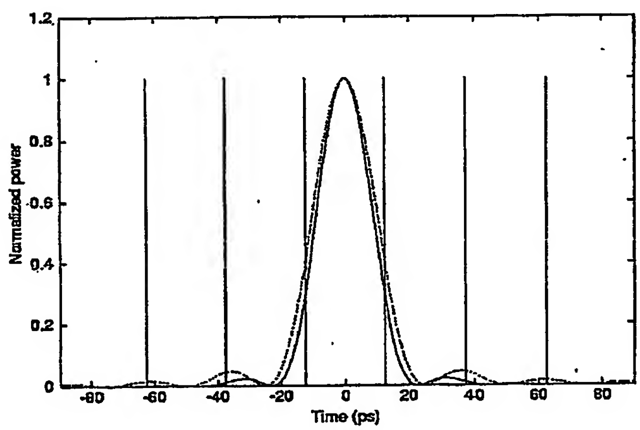

Fig. 1. Signal waveform before (top) and after (bottom) ideal square-like (dashed line) and 6-order super-Gaussian (solid line) optical filter

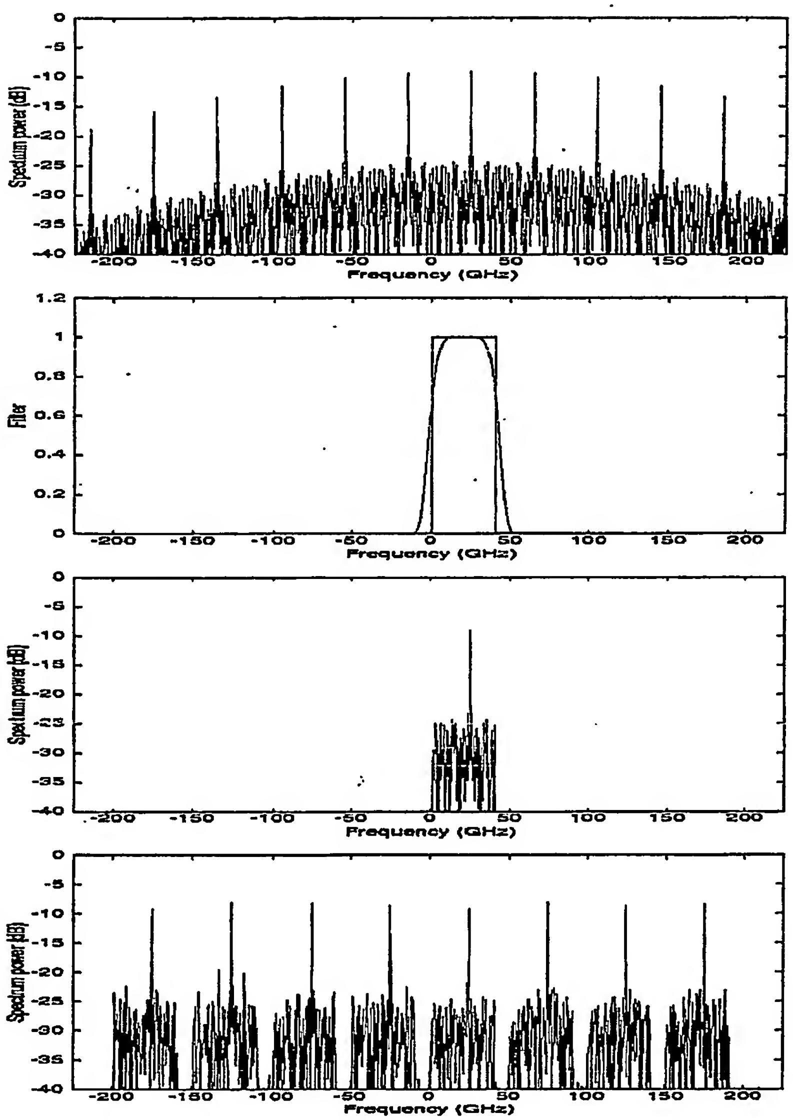

Fig. 2. From the top to the bottom: spectrum of the input short pulse before filtering (top); filter profile- ideal (solid) and super-Gaussian 6-th order (dashed); carrier spectrum after filtering; and WDM channels at the receiver (after 980 km) (bottom).

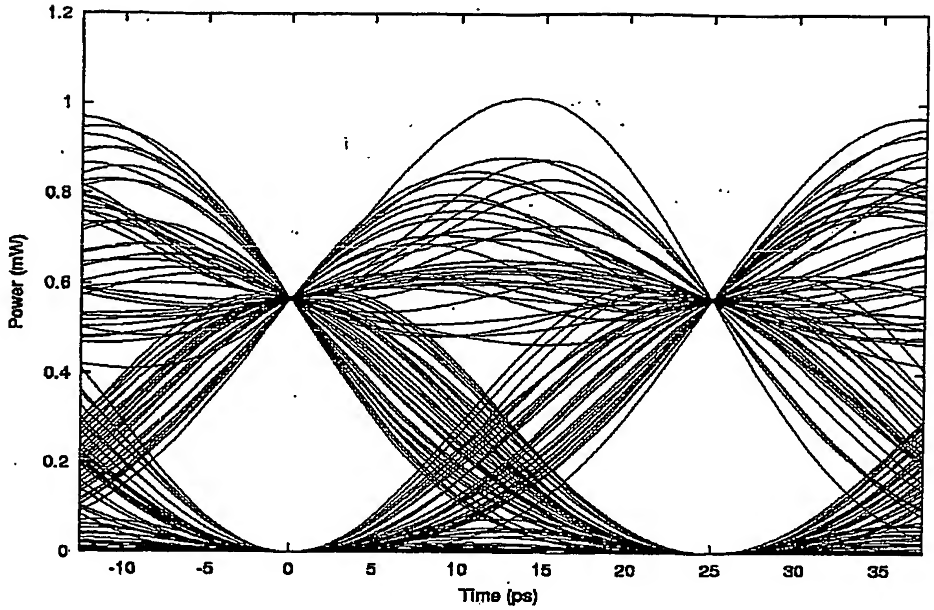

Fig. 3. Eye diagram of the input pseudo-random pattern constructed with sinc-shaped pulses.

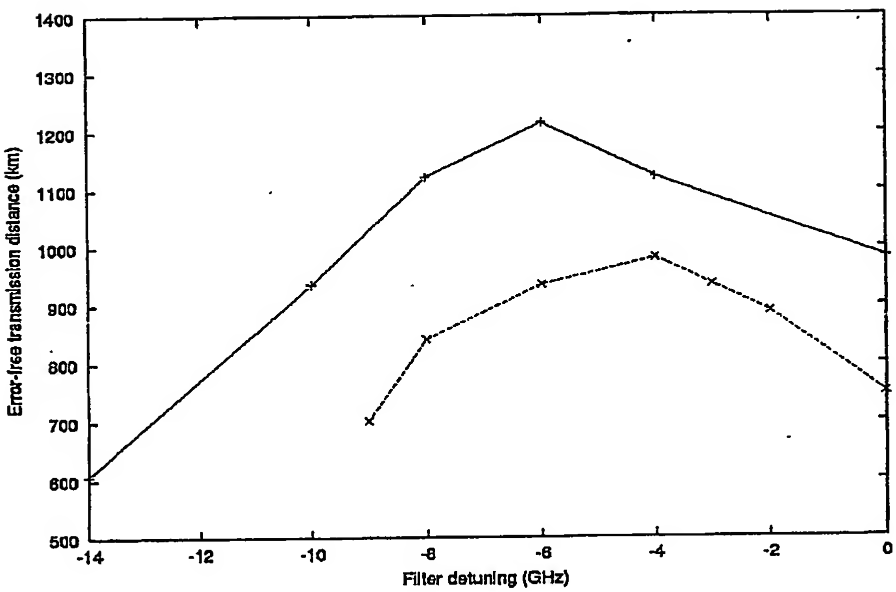

Fig. 4. Error-free transmission distance as a function of the optical filter detuning. Dashed line – ideal square-like filter; solid line – super-Gaussian filter of 6-th order.

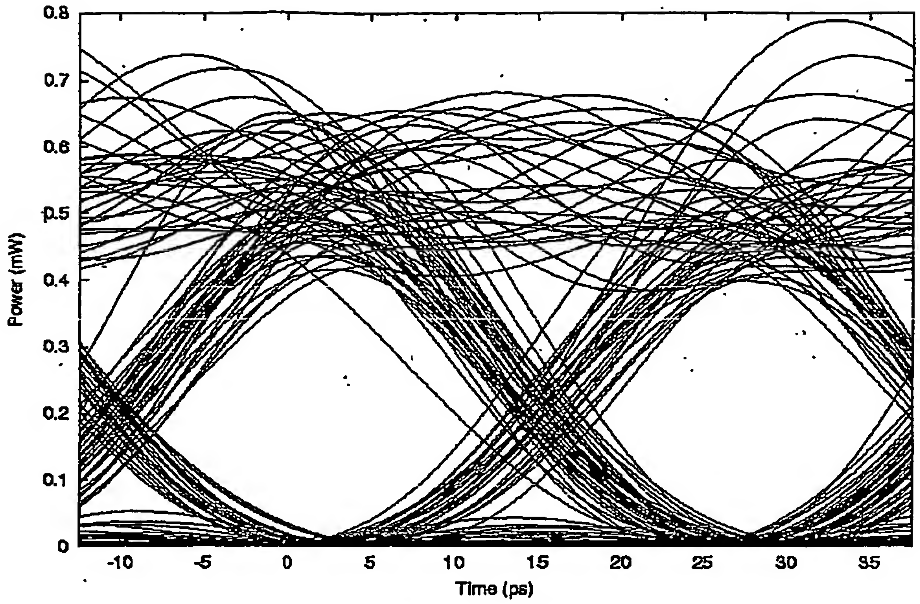

Fig. 5. Optical eye diagram after transmission over 1200 km

(super-Gaussian filter 6-th order, detuning –6 GHz as described in the text).

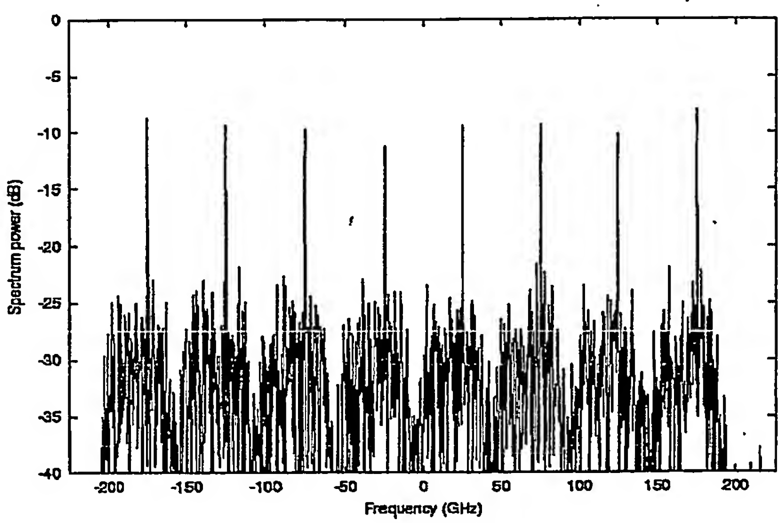

Fig. 6. WDM power spectra after transmission over 1200 km (same parameters as in Fig. 5).

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